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# PERFORMANCE/DESIGN AND PRODUCT CONFIGURATION SPECIFICATION FOR THE GRAVIMETER SENSOR COMPONENT OF THE LUNAR SURFACE GRAVIMETER

(Formerly ARD-501)

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## 1.0 SCOPE

The gravimeter sensor is an adaption described in U.S. Patent No, 2,293,437 which LaCoste and Romberg has manufactured for a number of years. The basic instrument movement is designated as the Short Range Model D Meter as described in letter from LaCoste to Larson dated November 10, 1969. Modifications include but are not limited to:

a. vibration restraint on the main spring,

b. tunnels on the springlets

c. beam position sensing by capacitor plates, area (nominal), 2 cm x 1 cm central plate thickness 0.016 inches. Plate spacing 0.020 inches from top of center plate to bottom of upper fixed plate and 0.020 from bottom of center plate to top of lower fixed plate

d. sensor period of 9.0 $\pm$1.0 seconds

e. mass changing mechanism

## 2.0 APPLICABLE DOCUMENTS

(1) L.J.B. LaCoste, et. al., Patent No. 2,293,437 (August 18, 1942).

(2) LaCoste, L., Letter outline of a method of measuring gravity difference between earth and moon, to J.V. Larson, November 10, 1969.

(3) IC 314133 Interface Control Specification for Lunar Surface Gravimeter Experiment.

(4) AL 900133 Performance and Design Requirements for Lunar Surface Gravimeter Experiment Subsystem.

(5) Bendix Drawing 2345862

(6) Bendix Drawing 2345865

## 3.0 REQUIREMENTS

### 3.1 PERFORMANCE

The design values given are based on the following nominal values for acceleration due to gravity; on earth, 980.7 gal; on the moon, 162.8 gal.

3.1.1 Inversion Temperature - The inversion temperature of the sensor shall be 50 $\pm 2^{o}$C.

3.1.2 Nominal Sensor Masses and Gravity (Acceleration) Ranges -

Effective mass of beam = $M_E$ ........... 22.5 $\pm$1gm

Center of earth range.................... 980.7 $\pm$0.7 gal

Total earth range of coarse and fine screws = $\Delta g_E$..................... 7540 mgal $\pm$10%

Total lunar range of coarse and fine screws = $\Delta g_S$ $(\Delta g_E)$ $(g_L)/g_E$...... 1252 mgal $\pm$10%

Lunar gravity range equivalent to incremental mass = $\Delta g_m$............. 0.9 $(\Delta g_s)$ $\pm$2%

Major lunar mass $M_L$ plus one increment lunar mass $\Delta M$. ..................... $M_E$ $(g_E/g_L - 1)$ $\pm$0.1%*

Each of 2 incremental lunar masses $\Delta M$. . 0.9 $M_E(\Delta g_E)/g_L$ $\pm$0.2%*

Overlap (approximately of mass and screw ranges)........................ $(1 - g_s/g_m)$ = 10%

*Manufacturing tolerances, actual masses used in each sensor must be determined within close limits, 0.001 gm.

Total lunar gravity range (3 - 2 x overlap) $\Delta g_s$..................3505 mgal $\pm$10%

### 3.2 USEFUL LIFE

The sensor shall be capable of performing as specified herein for a period of two (2) years, after a maximum storage period of three (3) years.

3.3 ENVIRONMENT

The design goal is that the sensor shall be capable of performing as specified herein during or after, as applicable, being subjected to the most severe environmental conditions or any logical combination of these environments applied simultaneously as specified in IC 314133. The application of these environments to the sensor within the LSG are as follows:

| | |
|---|---|
| Pressure: | 760 torr to 10 torr |
| Temperature: | $-20^{\circ}F$ to $+160^{\circ}F$ (in the caged position) |
| Shock Environment: | 20g - 11 msec sawtooth<br>($+X$, $\pm Y$, $\pm Z$ ALSEP axes) |

OPERATIONAL VIBRATION

| Axis | Frequency Range | Level |
|---|---|---|
| x, y, z | 20-80 Hz | +3 dB/oct |
| | 80-350 | 0.068 $g^2$/Hz |
| | 350-2000 | -3 dB/oct |

NOTES

1. The above levels are design limit (qualification). Acceptance levels are found by dividing the power spectral density by 1.69.

2. The required duration is 3.0 minutes for qualification 1.0 minutes for acceptance.

3. The required tolerance is as follows:

| | |
|---|---|
| 20-350 Hz | +3.0 dB<br>-1.5 dB |
| 350-2000 Hz | +4.5 dB<br>-1.5 dB |

4. During this test, operation shall consist only of measuring electrical continuity.

SINUSOIDAL VIBRATION

| Axis | Freq. Range | Dbl. Ampl. | Peak Acceleration |
|---|---|---|---|
| X | 5-14 Hz | 0.47 in | |
| (vertical) | 14-26 | | 4.8g |
| | 26-40 | 0.137 | |
| | 40-100 | | 11.2g |
| Y | 5-20 Hz | 0.265 in | |
| (UHT to | 20-40 | | 5.4g |
| CL) | 40-46 | | 0.9g |
| | 46-70 | 0.008 in | |
| | 70-100 | | 2.0g |
| Z | 5-14 Hz | 0.32 in | |
| (sunshield | 14-25 | | 3.2g |
| axis) | 25-34 | 0.10 in | |
| | 34-75 | | 6.0g |
| | 75-100 | | 1.4g |

NOTES

1. The above levels are design limit (qualification). Acceptance levels are found by dividng these acceleration levels by 1.3.

2. The required sweeprate is 3 oct/min.

3. The required sweep is 5-100-5 Hz for qualification and 5-100 Hz for acceptance.

4. The required tolerance is $\pm$10% on acceleration.

RANDOM VIBRATION (L&B)
1 MINUTES/AXIS SCAN

| Axis | Frequency Range | Level |
|---|---|---|
| X (vertical) | 20-34 Hz | +12 dB/oct |
| | 34-50 | 0.105 $g^2$/Hz |
| | 50-75 | +12 dB/oct |
| | 75-110 | 0.60 $g^2$/Hz |
| | 110-2000 | -15 dB/oct |
| Y (UHT to Inst. CL) | 20-22 Hz | +12 dB/oct |
| | 22-31 | 0.06 $g^2$/oct |
| | 31-43 | -24 dB/oct |
| | 43-70 | 0.0035 $g^2$ Hz |
| | 70-125 | +12 dB/oct |
| | 125-150 | 0.04 $g^2$/Hz |
| | 150-2000 | -24 dB/oct |
| Z (sunshield axis) | 20-30 Hz | +15 dB/oct |
| | 30-40 | 0.15 $g^2$/Hz |
| | 40 69 | -24 dB/oct |
| | 69-102 | 0.002 $g^2$/Hz |
| | 102-150 | +15 dB/oct |
| | 150-180 | 0.014 $g^2$/Hz |
| | 180-2000 | -24 dB/oct |

NOTES

1. The above levels are design limit (qualification). Acceptance levels are found by dividing the power spectral density by 1.69.

2. The required tolerance is $\pm 3$ dB or $\pm 10\%_{rms}$.

RANDOM VIBRATION (LUNAR DESCENT)
12.5 MINUTE/AXIS SCAN

| Axis | Frequency Range | Level |
|---|---|---|
| X (vertical) | 20-60 Hz | +6 dB/oct |
| | 60-105 | 0.30 $g^2$/Hz |
| | 105-2000 | -15 dB/oct |
| Y (UHT to Inst CL) | 20-22 Hz | +9 dB/oct |
| | 22-31 | 0.10$g^2$/Hz |
| | 31-45 | -24 dB/oct |
| | 45-70 | 0.005 $g^2$/Hz |
| | 70-100 | +12 dB/oct |
| | 100-150 | 0.02 $g^2$/Hz |
| | 150-2000 | -24 dB/oct |
| Z (sunshield axis) | 20-22 Hz | +3 dB/oct |
| | 22-38 | +12 dB/oct |
| | 38-52 | 0.3 $g^2$/Hz |
| | 52-84 | -24 dB/oct |
| | 84-105 | 0.0046$g^2$/Hz |
| | 105-140 | +15 dB/oct |
| | 140-180 | 0.02 $g^2$/Hz |
| | 180-2000 | -24 dB/oct |

NOTES

1. The above levels are design limit (qualification). Acceptance levels are found by dividing the power spectral density by 1.69.

2. The required tolerance is $\pm 3$ dB and $\pm 10\%$ $g_{rms}$.

3. It should be noted that Bendix will provide vibration isolation of the LSG experiment on the ALSEP pallet to pallet to provide higher confidence that input vibration levels will cause no significant problems The operating vibration levels specified are a workmanship test to be applied at the sensor while checking continuity of electronics with the sensor caged.

3.4 INTERFACES

3.4.1 Heater Box - The gravimeter sensor is enclosed in a rectangular metal box with heater wires embedded in the four sides of the box. A control thermistor is mounted on one side surface of the heater box and the temperature is held constant by a power control circuit using the thermistor signal. Therefore, the heater box is the basic source of the constant sensor temperature. The heater box cover serves as the sensor mount and as the base plate for the screw drives and arrestment gear trains.

The mechanical interface between the gravimeter sensor and the heater box shall be as shown in Bendix drawing 2345862.

3.4.2 Operating Drives - Four motor-driven operations are required for the sensor; Coarse screw, fine screw, arrestment (caging) and lunar mass-adding. The lunar mass-adding drive operates through the bottom of the heater box. The other three drives are connected to the sensor through the heater box cover.

One leveling drives external to the heater box shall provide for each horizontal axis, the sensor will be level trimmed by using a motor to drive its own mass plus appropriate added mass to shift the overall center of gravity of the sensor package. Consequently, the sensor package will swing into a new position on the gimbal.

All design values of gravimetric range and resolution have a tolerance of $\pm 10\%$ as a result of the tolerance of the basic spring stiffness. Each sensor will be calibrated to establish the exact values to the precision required by the Experiment objectives.

| | Coarse Screw | Fine Screw |
|---|---|---|
| Screw range (revolutions) | 90 | 41.7 |
| Gravity, earth, $\Delta g_{SE}$ (milligals) | 7500 | 40 |
| Encoder Resolution, microgal/bit (earth) | 18.3 | 0.1053 |
| Motor Step Increment, microgal/step (earth) | 14.9 | 0.0855 |

| | Coarse Screw | Fine Screw |
|---|---|---|
| Encoder/Counter, Ratio (revolutions) | 136:120 =1.133 | 5:9 = 0.56 |
| Counter Resolution (10 counts/revolution), microgal/count (earth) | 265 | 0.75 |
| Encoder Revolutions, stop to stop | 3402 | 2780 |
| Counter Revolutions, stop to stop | 2999.9 | 4999.9 |
| Motor Reducer Output Speed RPM Max (Equal to Encoder Speed) | 30.5 | 30.5 |
| Encoder/Screw Reduction Ratio | 37.8 | 66.7 |
| Screw Speed, RPM Max | 0.81 | 0.46 |
| Running Time, stop to stop min. at Max RPM | 115 | 91 |

Mass Adding Cap Drive $8^{+0}$- 1/4 Revolutions, stop to stop

Beam Arrestment (caging) Drive, 3 ± 1/16 Revolutions stop to stop

Leveling Drives Ranges shall produce ±6 arc-minutes nominal in each axis

(a) After assembly, backlash is not to exceed $\pm 1.4^{o}$ ($2.8^{o}$ total) @ 3 in oz maximum torque when applied to the coarse and fine feed meshes. Backlash movement is to be measured at the encoder coupling by restraining the pin coupling drive gear with a torque measuring device and such that no rotation of the pin drive gear is permitted when the encoder coupling is rotated. Backlash shall be measured at two positions of the pin coupling drive gear; one slected at random and the other $90^{o}$ from it.

3.4.3 Electrical - The gravimeter sensor interfaces electrically with the preamplifier circuit in the instrument housing assembly and the DC Bridge/AC coupling circuit in the electronics assembly.

3.4.3.1 Interface Circuits - The interface circuits are as shown in Figure 1.

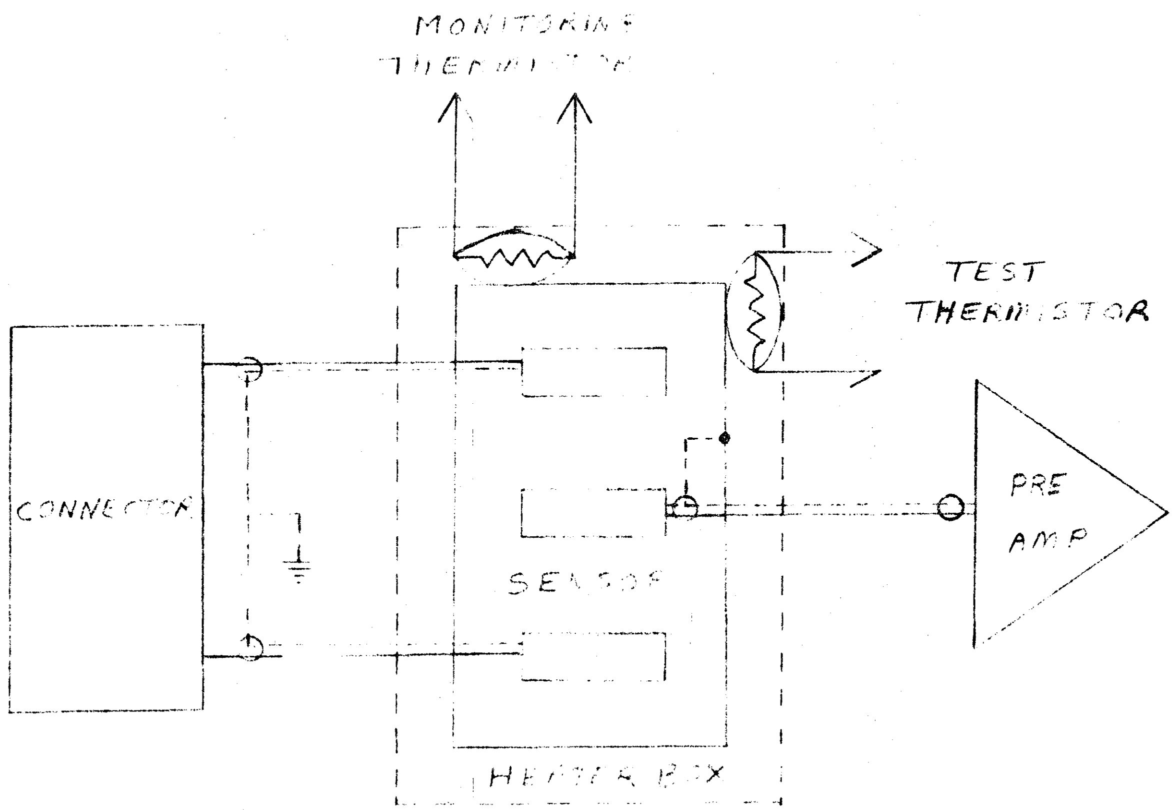
Paragraph 3.4.3.2 ammended to read as follows:

3.4.3.2 Interconnecting Wires - A total of seven electrical wires interconnect the gravity sensor with the other elements of the LSG experiment. One BELDEN 83265-100 coaxial wire is connected to the centerplate with the shield for the wire grounded to the sensor housing and the signal ground on the preamplifier. The wires connected to the upper and lower fixed plates will be a twisted pair of #26 AWG insulated wire. Two additional wires are connected to a test thermistor and two wires to a temperature monitoring thermistor both of which are mounted on the sensor housing. All wires shall be tagged or conspiciously marked for identification.

3.4.3.3. Temperature Monitors - Two thermistors are mounted on the sensor housing to monitor the sensor temperature both for test purposes and in flight."

3.4.4 Weight - The gravimeter sensor weight shall be 1.3 pounds ±0.1.

3.4.5 Configuration - The gravimeter sensor configuration shall be within the envelope defined in Bendix drawing 2345865.




Electrical Interface

Figure 1